Forecasting Needs for Distributed and Central Station Solar Generation

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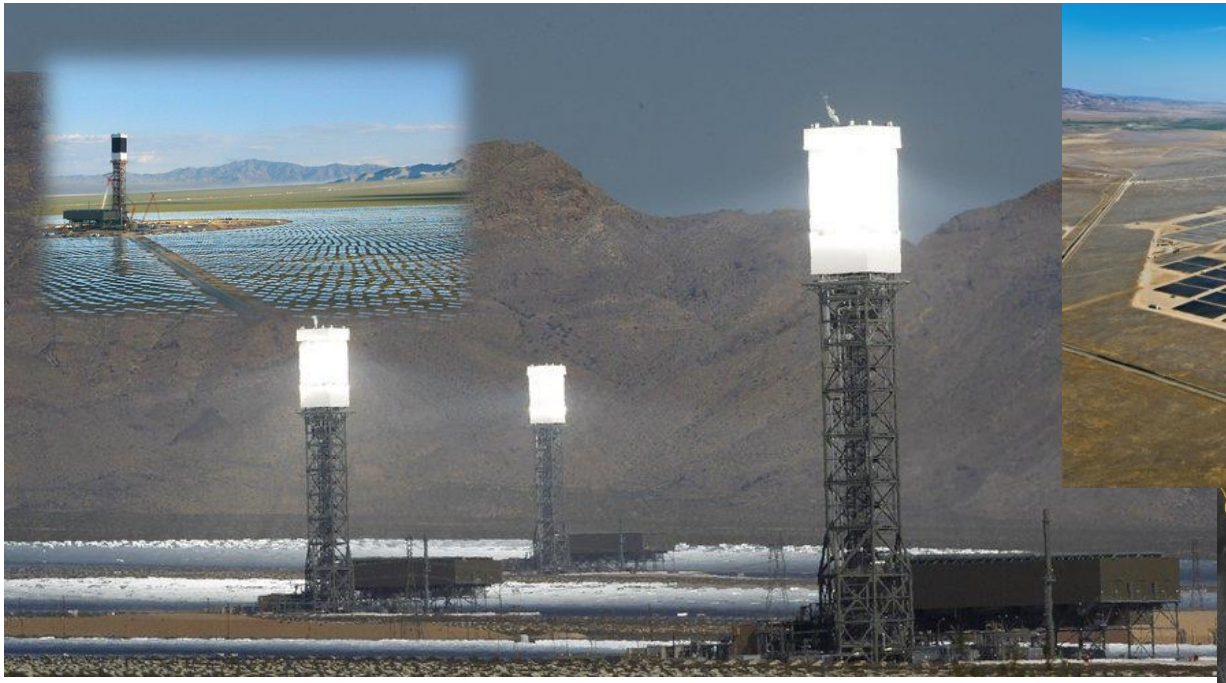
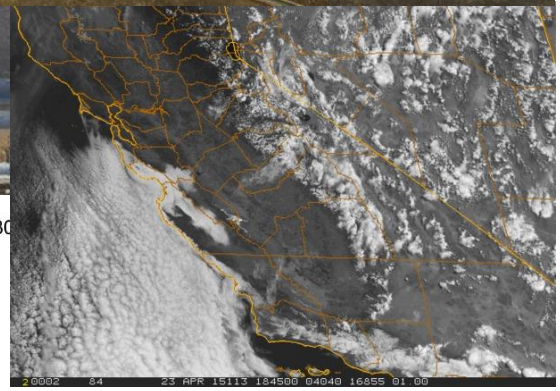
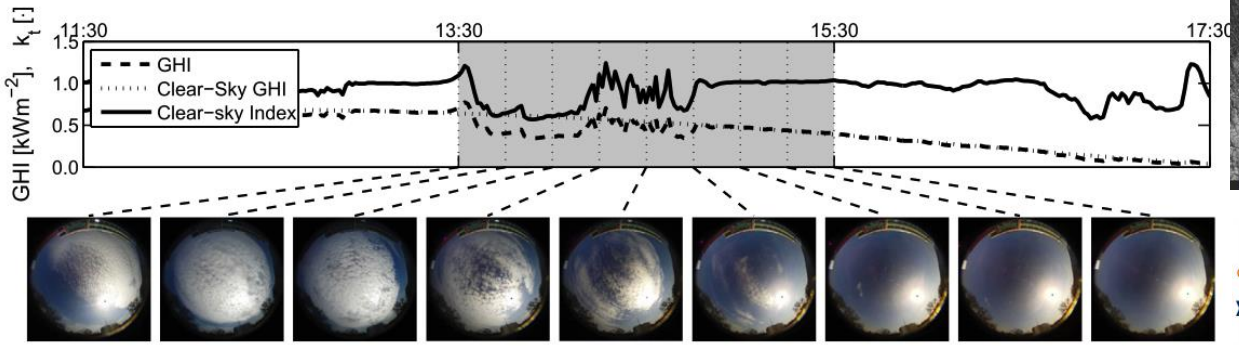
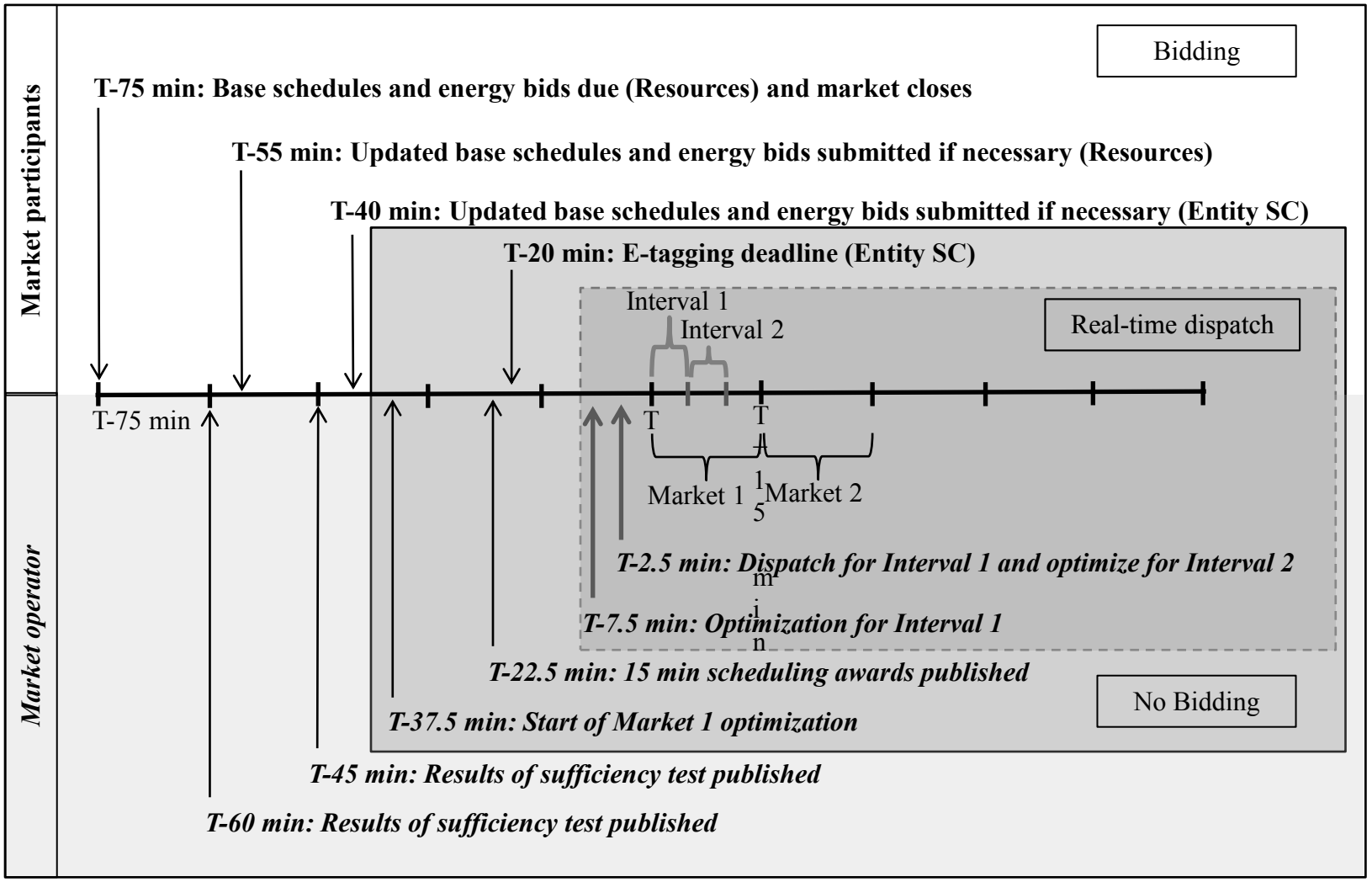






Temporal Horizons of Interest for the Energy Imbalance Market for the Western Interconnection



A. Kaur, L. Nonnenmacher, H.T.C. Pedro and C.F.M. Coimbra,
"Benefits of solar forecasting for energy imbalance market", Renewable Energy, **86**, pp. 819-830 (2016).

Targets for next-generation solar forecasts

Type of Generation:

Central generation

Real-time markets

Intra-hour forecasts

Operations and management

Intra-day forecasts

Scheduling

Day-ahead forecasts

Distributed generation

Day-ahead forecasts

Forecast horizons:

- Intra-hour forecasts (< 1 hour)
  - Reducing large errors, often associated with missing the onset of irradiance ramps caused by large-scale cloud movement.
- Intra-day forecasts (1 to 12 hours)
  - Improving the forecast in partly cloudy conditions – i.e. intervals with intermittent clearness index values
- Day-ahead forecasts
  - Improve synoptic cloud cover forecasts. Errors in local cloud cover day-ahead forecast lead to large errors in irradiance forecast.

Where are we in terms of solar forecasting?

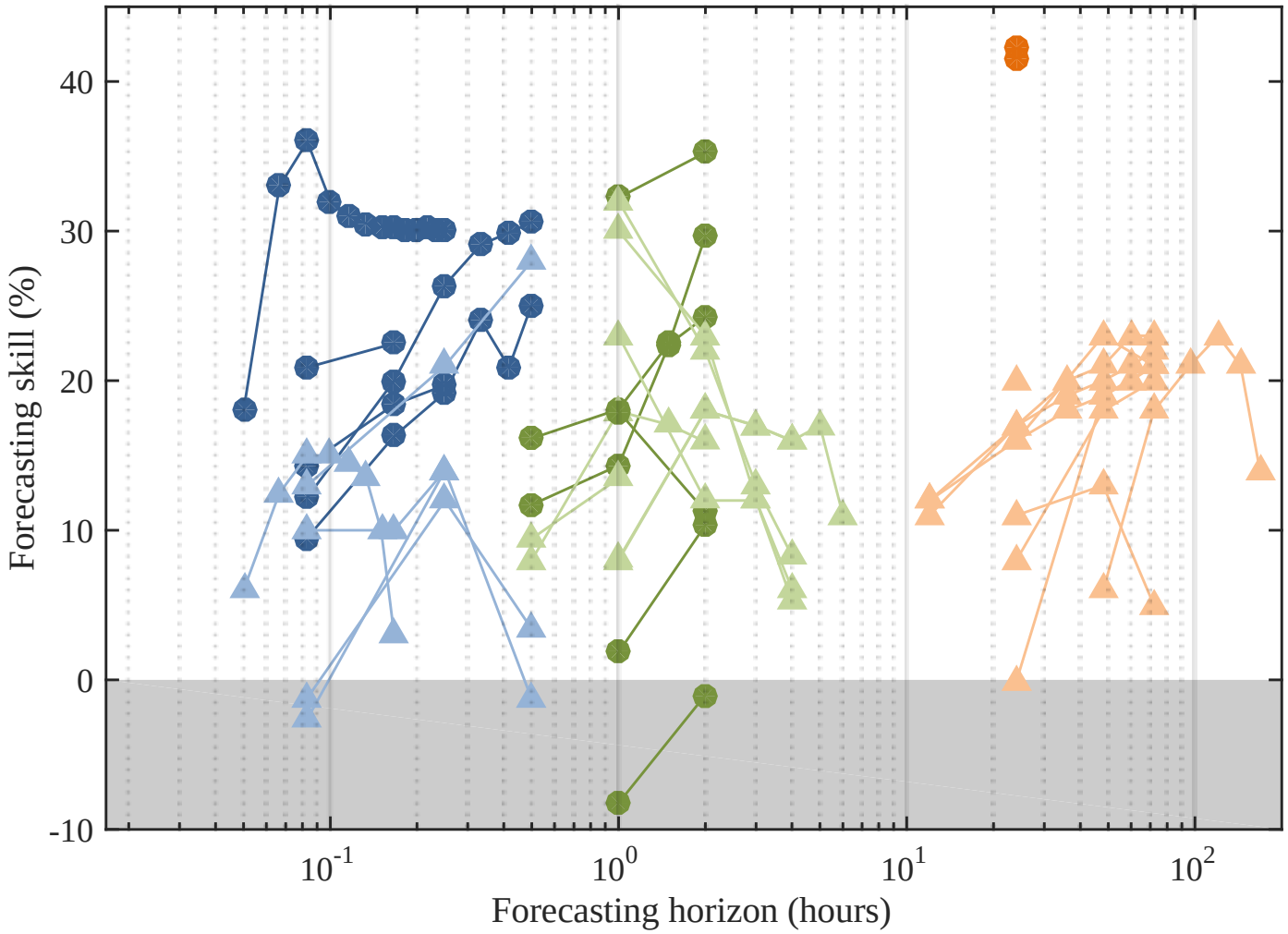
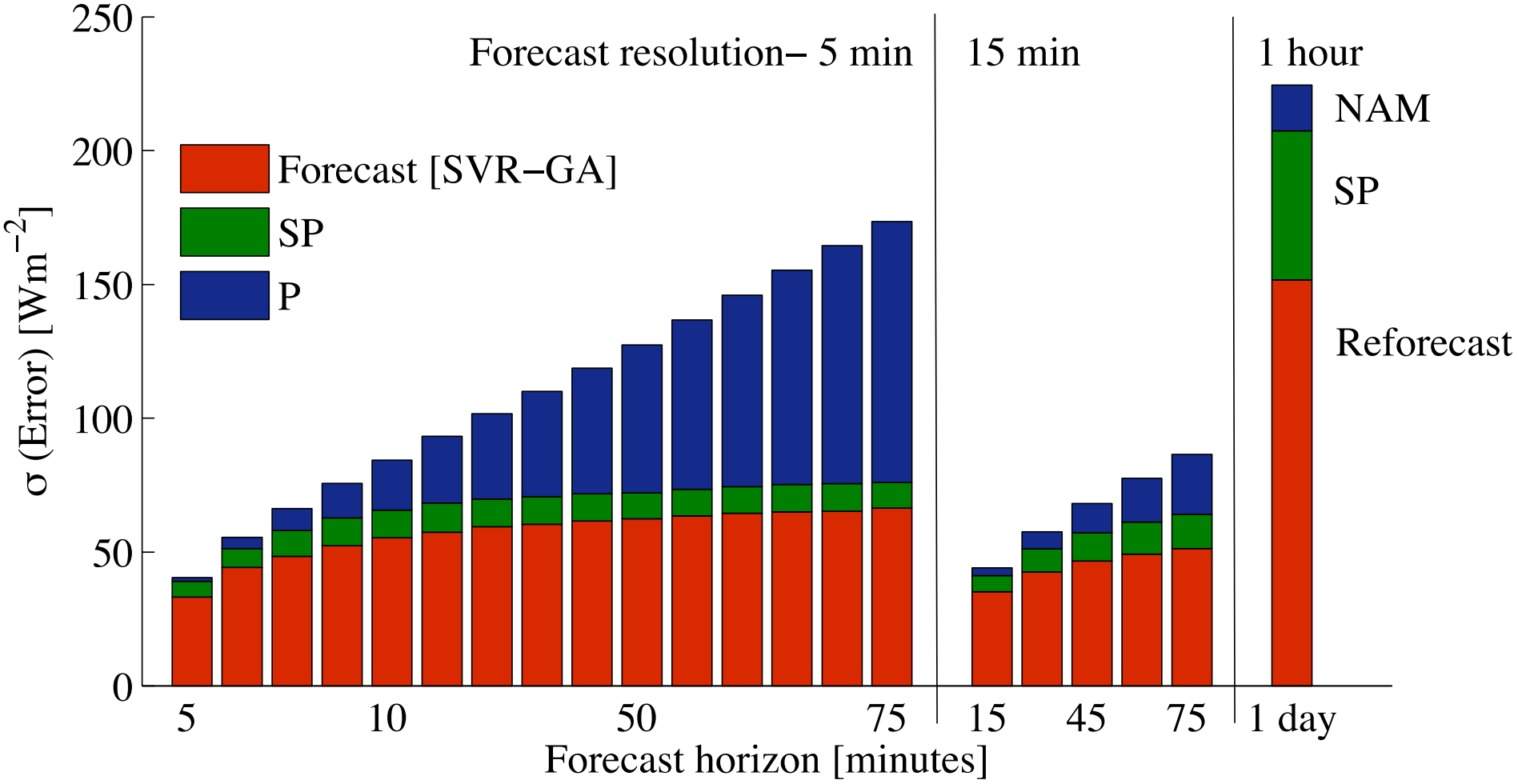


Figure 1: Comparison of forecasting skill of various peer-reviewed results. The comparison is limited to studies that list RMSE for the new proposed methods and persistence ($RMSE_p$). Forecasting skill is computed as $s = (1 - RMSE/RMSE_p) \times 100$. The colors indicate the different forecasting horizons: - 3 to 30 minutes, - 30 minutes to 6 hours, - 12 hours and longer. The symbol • indicates UCSD forecasts and the symbol N indicates other authors. Figure adapted from Inman, Pedro & Coimbra (2013).

Typical Solar Forecast Errors



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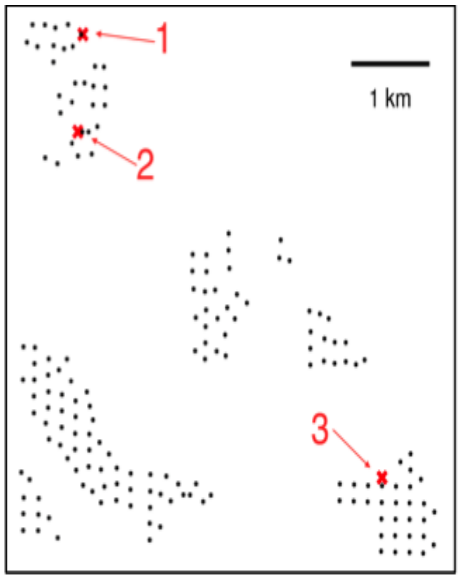
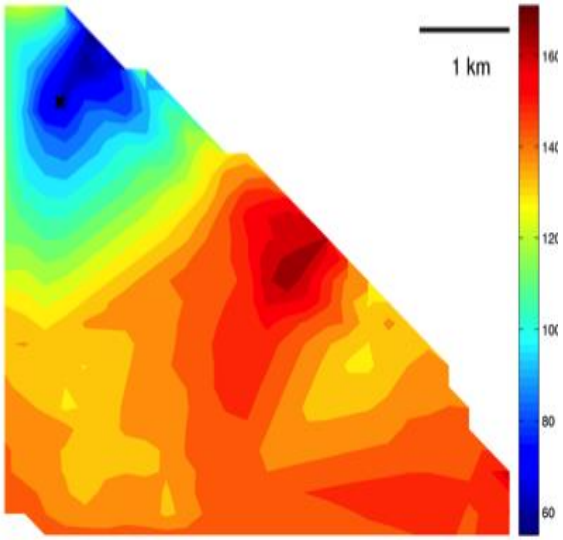
Spatially resolved irradiance maps

Irradiance sensors for a ~25km^2 solar farm

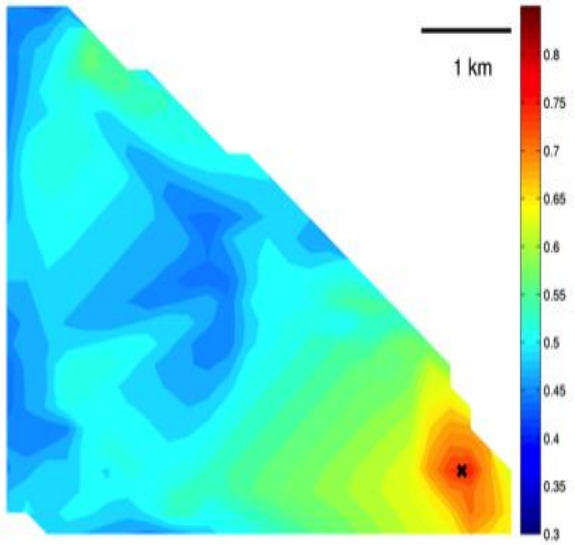


- Sparse irradiance data leads to poor forecasts for central generation plants.
- The correlation between irradiance measurements in two points decreases rapidly with the distance

Forecast error

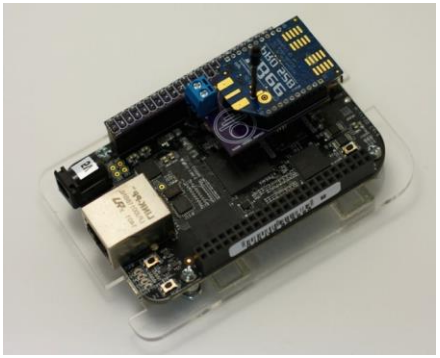


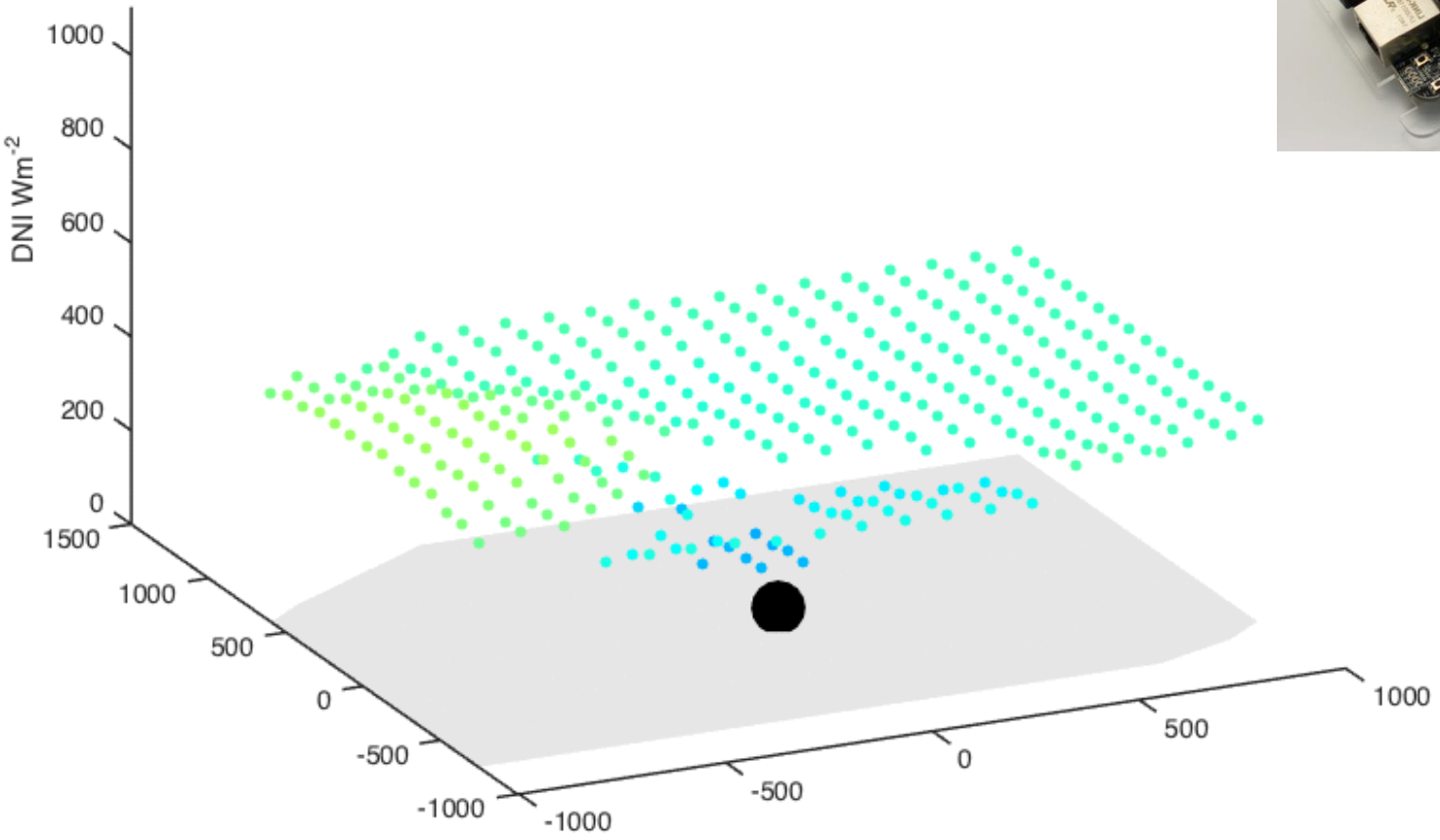
Irradiance spatial correlation



- Forecast performance based on data from few sensors decreases as the distance to the sensor increases.

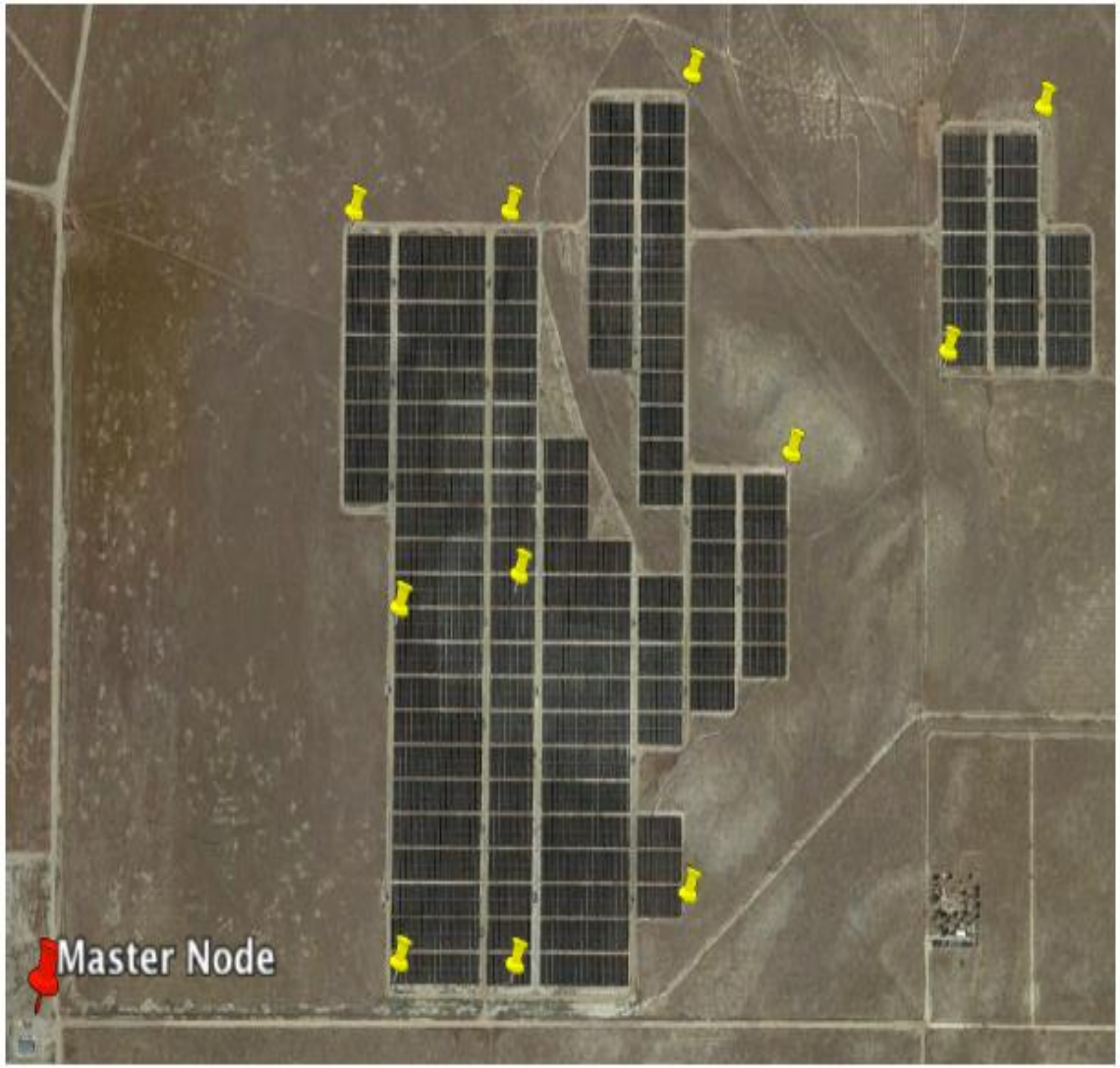
Solar Field Variability



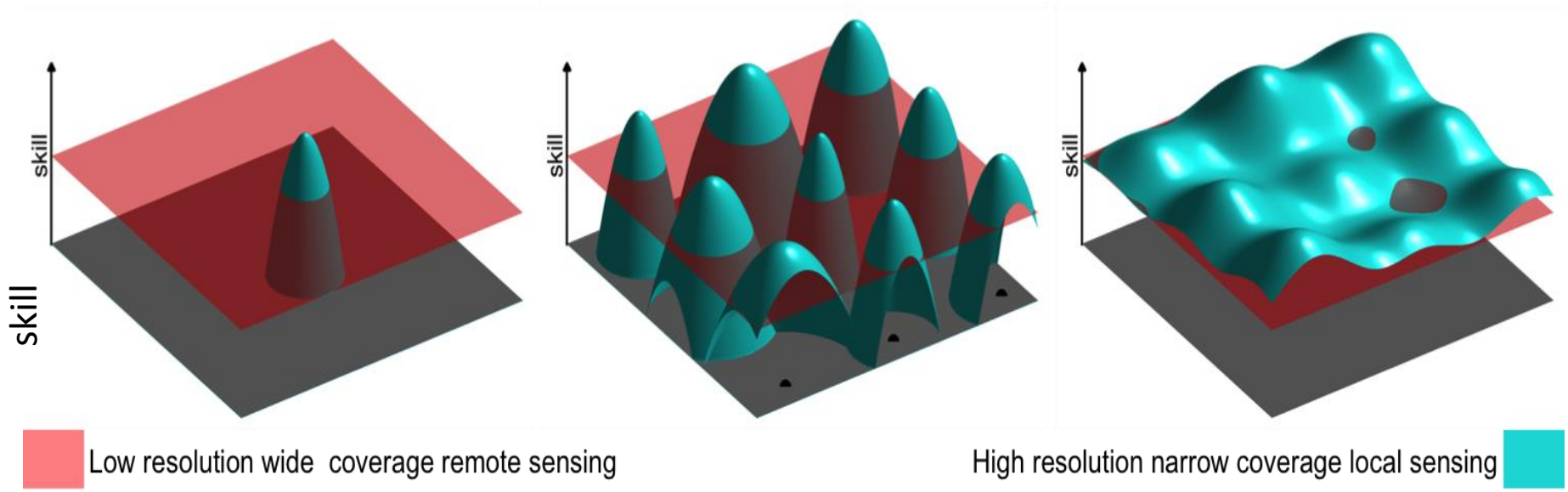


Improving telemetry: WSN field-tests for telemetry-intensive forecasts

Initial deployment at CVSR: sensor nodes (yellow) form a mesh network, with data pushed wirelessly towards the central receiver (red symbol). For nodes beyond the XBee wireless range (3.2 km), the nodes will automatically push their data to intermediate nodes, which will then forward the data to the central receiver. Twenty-four extra nodes were added in December, 2016.



Central generation forecast benefits from WSN irradiance data, which increases both coverage and resolution



Forecast based on a single sensor has a limited range. Outside of that range better forecast can be obtained with remote sensing methods (e.g. cloud motion from satellite images).

Using the data from many sensors will enable telemetry-intensive forecasting models that results in higher forecasting skills for the whole solar field.